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FORAMINIFERAL DIVERSITY OF BENDI LAGOON, EAST COAST OF INDIA

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ABSTRACT

The Bendi lagoon is isolated on the East Coast of India around the intersection of 18°40'N and 84°26' E. A total of 80 surface sediment samples were collected from 28 stations in May, August 1981 and January, May 1982 from Bendi lagoon. Diversity was measured for both living and total foraminiferal number in all the four seasons by using the statistical parameters such as species number (S), Shannon-Wiener information function H(S), and species equitability (E). Species number and Shannon-Wiener information function are usually relatively high in upper and south central lagoon and the diversity values are higher for TFN (total foraminiferal number) than LFN (Living Foraminiferal Number) and equitability is less for TFN in respect to LFN.

INTRODUCTION

The seasonal and spatial distribution of foraminifera of Bendi lagoon and their statistical relationship to various aspects of the environment is described in Yeruku Naidu (1983), Yeruku Naidu and Subba Rao (1988). The same study also investigated the foraminiferal number in terms of their diversity characteristics. An interest of this study is the analysis of the relation between diversity and environment.

Physiography, bottom water characters, substrate and organic matter contents of the sediments of the Bendi lagoon are well described in Yeruku Naidu (1983) and Yeruku Naidu and Subba Rao (1988). The general setting of Bendi lagoon and station locations are shown in Fig. 1.

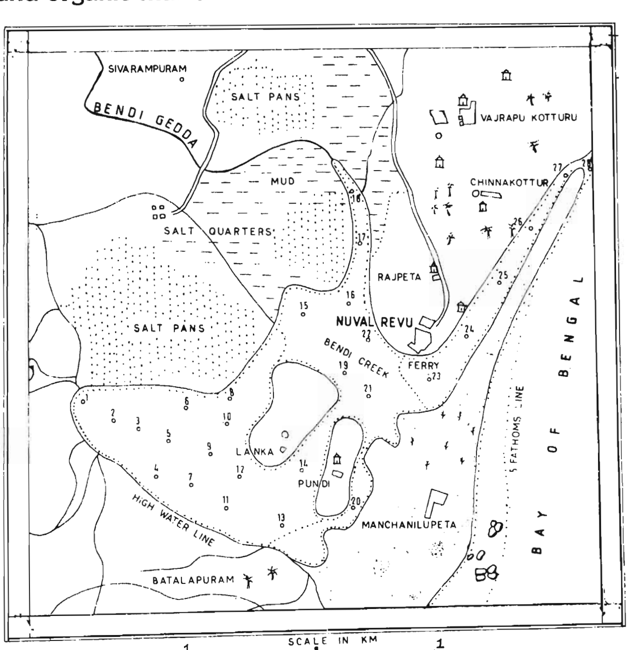

Fig. 1. General setting of Bendi Lagoon & Station Locations

DIVERSITY

Diversity expresses the relationship between the number of species present and the number of individuals. It provides a means of characterizing environment, independent of particular species present. Many measures of foraminiferal diversity have been used to describe foraminiferal ecological studies (Buzas and Gibson, 1969; Sengupta, 1979; Ariza, 1983; Williamson, 1985). "Because some diversity indices are weighted more heavily towards species richness and others more heavily towards species equitability or evenness, no single measure of diversity or community structure exists" (Boltovskoy and Wright, 1976).

The following measures of diversity are used in the present study:

1. Species number (S) in the assemblage. This is a very simple measure.
2. The Shannon-Wiener information function which is given by the equation $H(S) = \sum_{i=1}^{S} pi \log pi$ where S is the total species number and pi is the proportion of the i th species in the sample. It is much less dependent on the size of the sample than either the simple species diversity (S) or the Yule-Simpson index.
3. Species equitability (E) which is the ratio between the number of taxa required to yield observed diversity if distributed randomly among the species (e^H) and the actual number of taxa (Boltovskoy and Wright, 1976). It is given by the equation

Table 1. Species Number

Station No.	Living Foraminiferal Assemblage						Total Foraminiferal Assemblage					
	1981		1982		X̄	C	1981		1982		X̄	C
	May	Aug.	Jan.	May			May	Aug.	Jan.	May		
1	X	X	8	2	5	84	X	X	29	6	18	87
2	1	0	0	1	1	–	6	11	4	5	7	33
3	X	1	X	X	1	–	X	8	X	X	8	–
4	X	3	6	X	5	20	X	19	24	X	21	28
5	X	0	0	8	3	149	X	X	12	17	14	37
6	X	1	11	3	5	106	X	19	32	5	19	69
7	1	0	5	5	3	82	7	17	17	28	17	52
8	1	3		0	2	92	2	10	15	4	8	71
9	X	3	1	1	2	35	X	19	17	14	16	30
10	X	0	5	X	3	105	X	9	13	X	11	26
11	X	1	X	X	1	–	X	22	X	X	22	–
12	6	3	3	1	3	77	9	17	41	18	21	67
13	X	X	X	0	0	–	X	X	X	3	3	0
14	1	3	1	0	1	141	6	10	21	22	16	51
15	0	0	9	0	2	229	17	18	38	6	20	65
16	5	6	0	4	4	60	10	14	9	11	11	20
17	X	X	1	X	1	–	X	X	9	X	9	–
18	1	5	11	1	5	88	5	11	18	4	10	127
19	X	2	0	1	1	100	X	20	5	3	9	106
20	X	1	X	0	1	–	X	12	X	2	7	101
21	6	1	0	0	2	138	27	21	3	12	16	64
22	1	6	0	1	2	135	19	26	4	17	17	51
23	2	6	1	X	3	88	22	25	2	X	16	80
24	X	5	X	0	3	105	X	28	X	4	16	106
25	0	5	0	1	2	108	6	29	2	6	7	104
26	2	0	1	X	1	100	10	2	7	X	6	73
27	7	0	0	X	2	209	14	3	3	X	7	87
28	0	0	0	X	0	–	17	19	5	X	14	51
X̄	2	2	3	2			12	16	14	10		
C	86	108	120	221			69	49	66	88		

X̄ = Mean; C = Coefficient of variation; X = No data.

$E = e\frac{H(S)}{S}$ where E (equitability) will equal to 1.0 when all species are equally distributed. The ratio E is very similar to H(S)/lnS as a measure of equitability (Gibson and Buzas, 1973). Values for each of these indices were calculated for all the samples examined in the study.

RESULTS

SPECIES NUMBER (S)

Living species number is variable between 0-8 in May and August 1981 and May 1982, and 0-11 in January averaging 2-3 species per station. The seasonal mean living species number at different stations is variable between 0-5. Covariance values are high indicating considerable seasonal and spatial variations in living species number (Table 1). Living species number is always poor (0-2) in the tidal inlet, except in August, it is usually relatively high in the headward segment of the lagoon and also around the mouth of the Bendi gedda in January.

Total species number is variable between 2-27 in May 1981, 3-29 in August 1981, 2-41 in January 1982 and 2-28 in May 1982, averaging 12, 16, 14 and 10 respectively (Table 1). The seasonal mean total species number has a range from 3 to 22. Diversity as expressed by this number is low in the seaward half of the tidal inlet and high in the South-Central sector of the lagoon. Covariance values indicate that seasonal and spatial variations are not as pronounced as in living species number. The high species numbers in the total assemblages suggest that dead tests of some open sea forms are introduced into the lagoon.

SHANNON-WIENER INFORMATION FUNCTION H(S)

In respect of the living assemblages, the Shannon-

Table 2. Diversity - Shannon Wiener Function

Station No.	Living						Total					
	1981		1982		X̄	C	1981		1982		X̄	C
	May	Aug.	Jan.	May			May	Aug.	Jan.	May.		
1	X	X	1.7	0.7	1.2	58	X	X	2.1	1.5	1.8	23
2	0	0	0	0	0	0	0.2	1.7	1.2	1.0	1.0	65
3	X	0	X	X	0	0	X	1.3	X	X	1.3	0
4	X	1.1	1.5	X	1.3	22	X	1.5	2.5	X	2.0	46
5	X	X	0	1.7	0.9	24	X	X	2.2	2.0	2.1	7
6	X	0	2.1	1.1	1.1	93	X	2.2	2.1	1.5	1.9	26
7	0	0	1.5	1.5	0.8	116	0.8	1.6	1.9	1.8	1.5	37
8	0	0.7	0.4	0	0.3	121	0.5	1.3	1.9	1.0	1.2	46
9	X	0.5	0	0	0.2	135	X	1.8	1.5	1.9	1.7	124
10	X	0	1.1	X	0.6	142	X	1.9	X	X	1.9	0
11	X	0	X	X	0	0	X	1.6	X	X	1.6	0
12	1.0	0.7	0.3	0	0.5	90	1.7	2.3	2.1	0.9	1.8	29
13	X	X	X	8	0	0	X	X	X	0.5	0.5	0
14	0	0.8	0	0	8.2	200	1.4	1.7	2.0	2.1	1.8	18
15	0	8	1.9	0	0.5	198	1.8	1.0	2.0	0.9	1.4	37
16	0.8	1.4	0	1.1	0.8	72	1.8	1.9	1.5	1.5	1.5	24
17	X	X	0	X	0	0	X	X	1.7	X	1.7	8
18	0	1.3	1.4	0	0.7	115	1.4	1.7	1.2	1.1	1.4	19
19	X	0.6	0	0	0.2	175	X	1.3	1.3	1.1	1.2	11
20	X	0	X	0	0	0	X	1.9	X	0.6	1.3	74
21	1.1	0	0	0	0.3	196	0.9	2.0	0.7	1.4	1.3	83
22	0	1.6	0	0	0.4	200	0.6	1.8	1.3	2.0	1.4	42
23	0.2	1.6	0	X	0.6	145	1.8	2.1	0.7	X	1.5	48
24	X	1.6	X	0	0.8	141	X	1.6	X	1.2	1.4	20
25	0	1.4	0	0	0.4	200	0.8	2.0	0.6	0.7	1.1	63
26	8.6	0	0	X	0.2	175	1.3	0.6	1.2	X	1.1	37
27	1.4	8	0	X	0.5	172	1.6	0.3	1.1	X	1.0	66
28	0	0	0	X	0	0	2.6	2.0	1.5	X	2.0	28
X̄	0.34	0.58	0.52	0.32			1.23	1.63	1.56	1.3		
C	163	62	102	101			49	34	35	34		

X̄ = Mean; C = Coefficient of variation; X = No data.

Wiener index ranges from 0-1.7 in May and August 1981 and May 1982 and from 0-2.1 in January 1982. The index has zero value in the entire tidal inlet and in its headward area in January and May 1982. It is upward of 1.0 in the lower lagoon in May and August 1981 and in the upper lagoon in January and May 1982. The average index value shows that faunal diversity is greatest in August and January. The seasonal average index values of different stations indicate that diversity is greatest in the upper lagoon. Covariance values indicate that seasonal variations are more prominent than spatial variations in the index value (Table 2). In respect of the total assemblages, the index value ranging from 0.2-2.6 in May 1981, 0.3-2.3 in August 1981, 0.6-2.5 in January 1982 and 0.5-2.1 in May 1982, averaging 1.2, 1.6, 1.5 and 1.3 respectively. Values of 2.0 and above occur at the mouth of the tidal inlet in May 1981 at the head of the lagoon in January and sporadically in other seasons (Table 2). The seasonal mean value of the index at different stations has a range from 1.0 to 2.1. The relatively high mean values in the upper lagoon suggest that diversity in respect of the total foraminiferal fauna is higher here than in the tidal inlet. Covariance values suggest that seasonal and spatial variations in diversity of the total assemblage are much less impressive than in respect of the living assemblages.

SPECIES EQUITABILITY (E)

In respect of living foraminiferal fauna, equitability value ranges from 0.38 to 0.98, averaging 0.24, 0.39, 0.24 and 0.23 in May and August 1981 and January and May 1982 respectively. Equitability is of relatively high order in the headward area of tidal inlet in August and upper lagoon in January and May 1982.

Table 3. Equitability

Station No.	Living						Total					
	1981		1982		$\bar{X}$	C	1981		1982		$\bar{X}$	C
	May	Aug.	Jan.	May			May	Aug.	Jan.	May.		
1	X	X	0.68	0.99	0.84	25	X	X	0.28	0.77	0.53	62
2	0	0	0	0	0	0	0.21	0.48	0.80	0.55	0.51	47
3	X	0	X	X	0	0	0	0.46	X	X	0.46	0
4	X	0.94	0.76	X	0.85	12	X	0.23	0.48	X	0.36	42
5	X	X	0	0.67	0.34	138	X	X	0.74	0.45	0.60	33
6	X	0	0.73	0.98	0.57	89	X	0.48	0.24	8.91	0.54	63
7	0	0	0.87	0.90	0.47	105	0.33	0.28	0.40	0.21	0.31	19
8	0	0.67	0.36	0	0.23	148	0.82	0.38	0.43	0.71	0.59	34
9	X	0.56	0	0	0.19	168	X	0.31	0.27	0.48	0.35	34
10	X	0	0.62	X	0.31	142	X	0.74	0.28	X	0.51	65
11	X	0	X	X	0	0	X	0.22	X	X	0.22	0
12	0.44	0.68	0.43	0	0.39	72	0.63	0.55	0.20	0.14	0.38	63
13	X	X	X	0	0	0	X	X	X	0.57	0.57	0
14	0	0.72	0	0	0.18	200	0.66	0.54	0.35	0.37	0.48	52
15	0	0	0.72	0	0.18	200	0.35	0.15	0.19	0.41	0.38	39
16	0.44	0.64	0	0.75	0.46	96	0.27	0.45	0.52	0.41	0.41	27
17	X	X	0	X	0	0	X	X	0.59	X	0.59	0
18	0	0.73	0.38	0	0.28	125	0.79	0.51	0.19	0.77	0.57	47
19	X	0.91	0	0	0.30	177	X	0.17	0.73	0.95	0.62	65
20	X	0	X	0	0	0	X	0.57	X	0.91	0.74	31
21	0.49	0	0	0	0.12	204	0.08	0.34	0.68	0.32	0.36	108
22	0	0.85	0	0	0.20	215	0.19	0.24	0.94	0.42	0.45	76
23	0.62	0.79	0	X	0.47	83	0.28	0.32	0.98	X	0.53	74
24	X	0.97	X	0	0.49	245	X	0.18	X	0.84	0.51	92
25	0	0.83	0	0	0.21	200	0.37	0.24	0.95	0.33	0.47	68
26	0.95	0	0	X	0.32	172	0.37	0.95	0.46	X	0.59	54
27	0.59	0	0	X	0.20	178	0.36	0.43	0.95	X	0.58	55
28	0	0	0	X	0	0	0.82	0.37	0.89	X	0.69	41
$\bar{X}$	0.24	0.39	0.24	0.23			0.44	0.40	0.55	0.55		
C	123	80	103	198			40	9	45	36		

$\bar{X}$ = Mean; C = Coefficient of variation; X = No data.

The seasonal mean of E of different stations has a range from 0.12-0.85, being relatively high in the upper lagoon. The seasonal and spatial variations in E are significant as shown by covariance values (Table 3).

In respect of total fauna, the E value is variable between 0.08-0.98, averaging 0.44, 0.4, 0.55 and 0.55 in May and August 1981 and January and May 1982 respectively.The seasonal mean of E of different stations ranges from 0.22-0.74, the value being upward 0.5 at a majority of the stations. Seasonal and spatial variations in E value are much less prominent in the case of living fauna (Table 3).

DISCUSSION

Several hypotheses (Gibson and Buzas, 1973; Williamson, 1985) have been advanced to explain why areas have differing species diversities. Among these are climatic stability, competition, predation, productivity, spatial heterogeneity, time environmental predictability and various combinations such as productivity, stability and time stability. Foraminiferal assemblages are statistically linked to various aspects of the present marine environment, mainly temperature, salinity, depth and sediment characters (Williamson, 1985). Margalef (1963) suggested that if communities were undisturbed they would evolve from immature to mature ecosystems. He pointed out that a changing or unstable ecosystem will be less complex and less diverse than a more stable environment where succession will proceed toward an increase in complexity and more efficient utilization of energy, thus higher diversity. A) Living species number ranges from 0-11, usually relatively high in the upper lagoon, total species number has a range from 2-41 being relatively high in the south-central lagoon. B) Shannon-Wiener index in respect of living populations ranges from 0-2.1 and from 0.2-2.6 in respect of total populations. Diversity as expressed by this index is greatest in August and January and in the upper lagoon. C) Species equitability in respect of living populations ranges from 0.38-0.98 and from 0.08-0.98 in respect of total populations. The index is highest in the upper lagoon. Moderate to high values of S, H(S) and E in the upper lagoon may suggest the relatively stable environment than other part of the lagoon. Relatively low values of these indices are coincident with coarse substrate, turbulent high oxygen waters and are probably the result of the inability of many species of foraminifera to cope with this kind of stress. There are no long term data on the physical-chemical and biological variables for this area, neither magnitude nor variability for short or long duration is known. High diversity appears to reflect optimum conditions of temperature, salinity and the increased availability of nutrients. Stability and time are certainly important aspects of any environmental regime. Monthly observations of the foraminifera and ecological perameters for a period of 2-3 years and increase of sample density in the study area will be useful to evaluate the magnitude and variability of these diversity indices.

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